

# TESTING LAND EVALUATION METHODS FOR CROP GROWTH ON TWO SOILS OF THE LA PÉROUSE AREA (EASTER ISLAND, CHILE)

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## INTRODUCTION

In Easter Island history, agriculture played a vital economic role, be it out of the basic need to feed the population or, in a more advanced stage, to produce surplus food (Stevenson and Haoa 1999, Stevenson *et al.* 1999). Stevenson *et al.* (1999) state that agricultural production on Easter Island was generated by dryland agricultural systems, albeit designed to reduce agricultural risk.

Based on physical and socio-economic resources, land evaluation techniques enable the prediction of land performance. The land evaluation tool thus provides an insight into the land utilisation pattern of the past as well. Within this article, commonly used land evaluation methods are applied to soil sites in the La Pérouse area under present-day climatic conditions. Extrapolation to the past requires further research on past climate, management techniques and those socio-economic factors playing a decisive role in the land utilisation process.

## LAND EVALUATION METHODS

According to the Food and Agriculture Organization of the United Nations (FAO 1976), land evaluation is the process of assessing land performance for specific purposes. It deals both with physical resources, such as climate, landscape and soil, as well as with socio-economic resources, such as farm management, availability of manpower or market possibilities. Physical resources are relatively stable properties, whereas socio-economic resources are much more variable and dependent on political decisions.

Going from a general to a more detailed level, several land evaluation methods are commonly applied. At the most general level, we have the Land Capability Classification, established by the United States Department of Agriculture in 1961 (Klingebiel and Montgomery 1961). It comprises four types of capability classes. The qualifying terms used are vague and subjective. The land utilization type is not specified for one single crop. This method ignores socio-economic factors and is not related to a specific land utilization type.

More detailed, but still qualitative, is the Land Suitability Classification, based on a framework for land evaluation of FAO (1976). This is a crop specific method. Four suitability classes are recognized, S1, suitable, S2, moderately suitable, S3, marginally suitable and N, unsuitable. Subclasses are attributed according to the characteristics that limit crop growth. This method is designed for physical and socio-economic evaluation, but it is rarely applied as such.

For a quantitative approach, we note the multivariate

statistical modeling. A widely used example of this type is the 3 level hierarchical crop growth model of FAO (1978). The first level deals with the Radiation-thermal Production Potential, where production is only determined by photosynthesis and respiration of the crop. Here, no other limiting factors such as water stress, pests or diseases are considered. On the second, the Water-limited Production Potential level, water stress is taken into account. On the third, Land Production Potential level, the limiting nature of soil characteristics and management practices is considered as well. The final production determined by this Land Production Potential might be somewhat reduced when compared to the first level Radiation-thermal Production Potential.

Finally, dynamic modeling is the most detailed method, but requires correspondingly the most detailed database.

## FAO LAND SUITABILITY CLASSIFICATION FOR RAINFALL AGRICULTURE

The Land Suitability Classification for rainfall agriculture of FAO will be illustrated with data from the La Pérouse area under present-day climatic conditions for the sweet potato crop.

To achieve this, climate, landscape and soil characteristics are needed. Monthly climatic data of temperature, precipitation, relative humidity and insolation are collected. Landscape characteristics, such as slope, flooding and drainage are also considered. Physical soil characteristics include soil depth (i.e. effective rooting depth), texture, calcium carbonate content and gypsum content. Soil fertility characteristics comprise apparent cation exchange capacity (ACEC), sum of the basic cations (Ca, Mg, K), acidity (pH-H<sub>2</sub>O) and organic carbon (OC) content. Salinity (electrical conductivity, EC) and alkalinity (exchangeable sodium percentage, ESP) are considered too.

In the next step, the collected and calculated climate and land characteristics are compared with the crop requirements. Following the simple limitation method, the final climatic and land suitability class is attributed according to the least favorable characteristic. Following the limitation method regarding number and intensity of limitations, suitability classes are attributed according to the number and intensity of limitations. In the parametric method, a rating is attributed to each evaluated characteristic. Optimal conditions represent a rating of 100. The individual ratings are used to calculate an index (Sy) based on the Storie method ( $Sy = \prod R_j$ ) or the Square Root method ( $Sy = R_{min} \times \sqrt{\prod R_j}$ ), where  $\prod$  means product,  $R_{min}$  is the lowest rating value and  $R_j$  is the rating value for the  $j^{th}$  soil factor. The suitability classes are then attributed depending on the value of the climatic and land indices.

## DATASET

## Climate

The present-day climate of Easter Island (Figure 1), based on the meteorological data from Mataverí (Latitude: 27°10' S, Longitude: 109°26' W, Elevation: 41 m) and according to the data of FAO (1985), is subtropical. The average annual temperature is 20.4° C; the mean minimum and maximum temperatures over several years are 16.9 and 24.0° C. On average, July and August are the coldest months and February is the warmest month. The average precipitation is 1,091 mm. We assume however that the precipitation roughly varies between 1,000 and 1,500 mm over the island, following the topographic position (altitude and orientation of slopes).

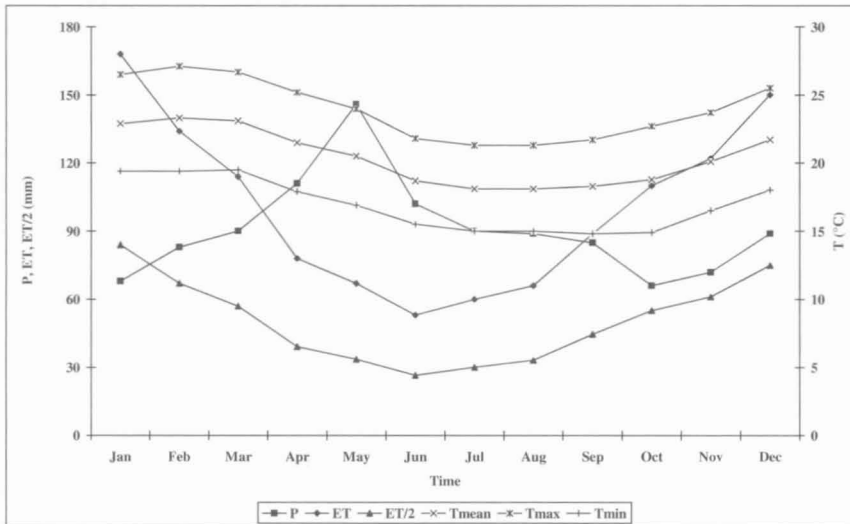


Figure 1. Precipitation (P), evapotranspiration (ET), mean, maximum and minimum temperature (T) at Mataverí (FAO, 1985)

The annual evapotranspiration is 1,211 mm. On monthly basis however, we observe that the precipitation exceeds the evapotranspiration from the beginning of April until the middle of September (Figure 1). According to the FAO concept (Kowal 1978), this period is indicated as the humid season. The growing period, determined by the period when the precipitation exceeds half of the evapotranspiration, plus the number of days required to evaporate an assumed 100 mm of soil water (Kowal 1978), spreads over almost the whole year.

## Soil

Tables 1 and 2 give the soil analytical data for the La Pérouse profiles 1 (LP1) and 3 (LP3). Profile LP1 is situated on the higher, flat part of a lava plateau. The slope in South-North direction is about 2.5%. The substratum has less than 50 % SiO<sub>2</sub> (P. De Paepe personal communication), and the parent material is considered to be a secondary volcanic ash deposit mixed with some weathering products of the neighboring rock outcrops. LP1 is well drained. The surface is covered with 15-20% of scattered stones with a diameter between 0.10-0.20 m. Within LP1, we distinguish 5 horizons. The A-horizon is 0.40 m thick. The rock substratum appears at 0.85 m and limits the rooting depth. Within LP1, we can distinguish two units, based on a

different mineralogy. The lower unit shows (1) an increase in cation exchange capacity (CEC), probably because the pH in the field is lower than the one of the laboratory treatment (pH 7), (2) a decrease in clay content due to a lack of dispersion in the laboratory and (3) a dramatic increase in apparent cation exchange capacity (ACEC), due to overestimating the CEC and underestimating the clay content (standard pipette method). The organic carbon (OC) content is high throughout the whole profile. The phosphate content (P<sub>2</sub>O<sub>5</sub>), extracted following the Olsen method, is low. This might be due to phosphate retention in the soil complex, which hampers phosphate uptake by the crop.

Profile LP3 is situated in a flat-bottomed depression. The site has a slope of about 1% in South-North direction. The substratum has less than 50% SiO<sub>2</sub> (P. De Paepe personal communication), and the parent material is also here considered to be derived from volcanic ash deposits mixed with some weathering products of the neighboring rock outcrops. The soil is well drained. The surface has only a few percent of stones with a diameter between 0.10-0.20 m. Up to a depth of 1.80 m, we distinguish 5 major horizons. The A-horizon is about 0.60 m thick even though roots can penetrate until about 2 m. Within profile 3, we can also distinguish two units. LP3 has comparable values for CEC, clay content and ACEC, as LP1, but the difference between the soil units is more of a contrast in LP3 than in LP1. The organic carbon content is relatively high throughout the whole profile. The phosphate content is again low, even extremely reduced in the lower soil horizons. The phosphate retention might be higher within this unit.

## Crop data

Based on archaeobotanical data (Orliac and Orliac 1996, 1998a, 1998b), we know which crops were commonly grown for cooking purposes on the Easter Island from the 14<sup>th</sup> to the 17<sup>th</sup> century. Sweet potato made up an important part of the diet. Ti and sugar cane were also used, however, not as direct food remains; they were rather used as earthen covering. Climate, landscape and soil requirements for present-day cultivars of sweet potato are taken from Sys et al. (1993).

## RESULTS

We applied the crop specific FAO land suitability classification on the profiles LP1 and LP3 for the sweet potato crop. The actual climatic, landscape and soil data were compared with the crop requirement data for sweet potato and the different parameters were evaluated as specified in the land suitability classification method. For the start and end of the crop cycle, as well as for the duration of the different crop development stages, we assumed theoretical values. Based on the balance between precipitation and evapotranspiration, we calculated that the growing period on Easter Island theoretically starts at the beginning of February. The crop cycle length was estimated at 150 days, comprising an initial stage of 40 days, a crop development stage of 40 days, a mid-season stage of 40 days and a late-

Table 1. Soil analytical data for soil profile La Pérouse 1

P	H	Depth cm	Clay w %	Silt w %	Sand w %	>2mm vol %	pH (H <sub>2</sub> O) 1/5	pH (KCl) 1/5	OC %	P <sub>2</sub> O <sub>5</sub> ppm	ACEC	CEC	Ca	Na	Mg	K	ESP %
LP1 1	A1	0-11	44.8	50.2	5	2.0	5.1	4.6	4.53	54	56	25.0	4.8	0.4	4.3	0.2	1.4
2	A2	11-25	51.4	46.0	2.6	0.8	5.3	4.6	2.58	24	34	17.6	2.0	0.3	2.5	0.0	1.9
3	A3	25-40	42.9	50.7	6.4	0.0	5.5	4.7	2.36	26	43	18.3	1.6	0.5	2.0	0.0	2.5
4a	B1	40-60	14.1	56.4	29.5	0.0	5.3	4.9	6.03	29	342	48.2	0.8	0.3	0.4	0.0	0.6
4b	B2	60-85	11.8	62.6	25.6	0.0	5.1	4.8	6.43	32	392	46.2	0.5	0.3	0.1	0.0	0.6
5	R	85-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Soil analytical data for soil profile La Pérouse 3

LP3 1	A1	0-15	34.8	49.6	15.6	0.5	5.4	4.6	2.67	145	62	21.7	2.6	0.5	3.5	0.4	2.5
		15-45	49.0	48.0	3.0	0.0	5.1	4.2	2.31	134	43	21.3	1.4	0.6	2.0	0.1	2.7
2	A2	45-63	22.9	45.3	31.8	0.0	4.8	4.5	1.69	22	66	15.0	0.7	0.4	1.0	0.1	2.9
3	B1	63-83	27.6	58.9	13.5	0.0	4.8	4.5	1.54	9	50	13.7	0.5	0.4	0.6	0.0	3.2
4	B2	83-110	20.1	40.2	39.7	0.0	4.7	4.8	2.97	6	113	22.8	<0.2	0.2	0.1	0.0	0.9
5a	2Ab 1?	110-150	4.7	40.5	54.8	0.0	4.6	5.0	4.31	5	898	42.2	0.2	0.1	0.1	0.0	0.3
5b	2Ab 2?	150-165	5.2	53.6	41.2	0.0	5.0	5.1	4.38	4	821	42.7	0.5	0.1	0.6	0.0	0.3
6		165-200	4.7	51.3	44.0	0.0	5.0	5.2	4.19	4	964	45.3	0.3	0.1	0.4	0.1	0.2

season stage of 30 days. We assumed a low level of management, which means animal traction or handwork according to Sys et al. (1993).

Table 3 gives an overview of the land suitability classification method applied to La Pérouse profile 1 for sweet potato. Different aspects of precipitation, temperature, relative humidity and insolation were evaluated to determine the climatic suitability. We observe that relative humidity is the most critical climatic factor for sweet potato production, giving a rating of 69, as compared to 100 when no limitations are present. Under the present-day climate of the Easter Island, the land suitability classification attributes a S2-class for sweet potato, which means that the Easter Island on this basis is moderately suitable for sweet potato.

In a next step we considered landscape (slope, flooding), soil physical characteristics (drainage, texture, soil depth), soil fertility characteristics (ACEC, pH, OC), soil salinity and alkalinity. For the overall evaluation, only the most limiting parameters were withheld. It seems that soil fertility, especially pH that gives a rating of 85, is more limiting for sweet potato production on the LP1 soil than physical soil characteristics or salinity/alkalinity. We should however mention that texture as well as apparent cation exchange capacity needs to be analyzed more adequately, as discussed earlier.

Within this preliminary approach, the La Pérouse profile 1 is moderately to marginally suitable, depending on the calculation procedure, for sweet potato production. The climate represents the most limiting crop growth factor, indicated as sub-class c.

Table 4 gives an overview of the land suitability classification method applied to La Pérouse profile 3 for sweet potato. When considering the specific landscape and soil properties of LP3, we obtain comparable results as for LP1. On the LP3 soil as well, pH is a limiting factor for sweet potato production. Also here, we face the analytical problems for texture and CEC determination.

LP3 seems moderately to marginally suitable for sweet potato production. The climate again represents the most limiting crop growth factor (sub-class c).

## DISCUSSION

When applying standard land evaluation methods on the **present** database of the Easter Island, we encountered a set of problems. Especially in the case of soils developed in volcanic sediments where topsoil and subsoil often have a different mineralogy, (probably according to the weathering stage of the parent material), but they are treated as a single unit (Humphreys 1998). These different units can also have an impact on the root depth, which is an important criterion in the land evaluation.

In case of buried surface horizons, we should try to retrace the pedo-chronostratigraphy in order to know at which level to apply the land evaluation. As far as currently known, no volcanic activity has occurred since 2,000 years BP (Charola 1997), and as well before the Polynesian occupation of the island. The question of anthropogenic colluvium outside habitat areas is however still under debate (Louwagie and Langohr 2002).

Tables 3 and 4. FAO Land suitability classification applied to the soil profile of La Pérouse 1 and La Pérouse 3

Climatic station: Mataverí, Easter Island

Crop: Sweet potato: (*Ipomoea batatas*)

Crop cycle length: 150 days; start = 1 Feb; end = 30 Jun; I = 40; CD = 40; MS = 40; LS = 30

Management: low level, animal traction or handwork

		Table 3. La Pérouse 1				Table 4. La Pérouse 3			
	Characteristics	Value	Class	No Lim	Rating	Value	Class	No Lim.	Rating
	<i>Climatic parameters</i>								
	Annual precipitation (mm)	1091	S1	0	96.5	1091	S1	0	96.5
	Number of dry months in Growing cycle ( $P < ET_0/2$ )	0	S1	0	100	0	S1	0	100
	Mean temperature Growing cycle (°C)	21.4	S2	2	77.8	21.4	S2	2	77.8
c	Mean minimum temperature Growing cycle (°C)	17.8	S1	0	95.8	17.8	S1	0	95.8
	Relative humidity at Harvest (%)	81.6	S2	2	68.6	81.6	S2	2	68.6
	n/N Development stage (Mar2-Apr2)	0.50	S1	0	95.0	0.50	S1	0	95.0
	n/N Maturation stage (Jun1-Jun3)	0.40	S2	2	80.0	0.40	S2	2	80.0
	Climatic index (Storie/square root method)				41.2/53.1				41.2/53.1
	Climatic rating (Storie/square root method)				53.7/64.5				53.7/64.5
	Climatic class		S2	2	S3/S2		S2	2	S3/S2
	<i>Landscape and soil characteristics</i>								
t	Slope (%)	2.6	S1	0	96.7	1	S1	0	98.8
w	Flooding	-	S1	0	100	-	S1	0	100
w	Drainage	well	S1	0	100	well	S1	0	100
	Texture	SiCL	S1	0		SiCL	S1	0	
	Clay (%)	39.7				37.5			
	Silt (%)	59.2			96.3	48.9			99.0
s	Coarse fragments (vol%)	0.7	S1	0		0.3	S1	0	
	Soil depth (cm)	85	S1	1		>100	S1	0	
	CaCO <sub>3</sub> (%)	-	S1	0	100	-	S1	0	100
	CaSO <sub>4</sub> (%)	-	S1	0	100	-	S1	0	100
	Apparent CEC (cmol[+] kg <sup>-1</sup> clay) <sup>2</sup>	369	S1	0	100	79	S1	0	100
f	Sum of basic cations (cmol[+] kg <sup>-1</sup> )	6.7	S1	0	100	5.3	S1	0	100
f	pH H <sub>2</sub> O	5.21	S1	1	85.2	5.3	S1	1	86.0
	Organic carbon (%)	3.44	S1	0	100	2.5	S1	1	90.3
n	EC (dS m <sup>-1</sup> )	-	S1	0	100	-	S1	0	100
n	ESP (%)	2.51	S1	0	100	3.24	S1	0	100
	Land index (Storie/Square root)				42.6/57.4				40.8/56.2
	Actual suitability		S2c	2	S3c/S2c		S2c	2	S3c/S2c

Another important problem are the texture data obtained with the routine analytical method on poorly weathered volcanic ash soils. These data are not reliable due to insufficient dispersion of the soil material. It is thus not correct to put these data directly into the existing classification systems.

Data of cation exchange capacity on recent volcanic ash

are estimated to be too high. The charge of the soil complex in these soils is mainly a variable charge, highly depending on the field pH, whereas the CEC is determined at a fixed pH of 7 in the laboratory.

Finally, these soils may suffer from a high phosphate retention capacity, which means that the phosphate is not avail-



able for the crop. This particular soil parameter is however not considered in the commonly used methods, as for example the crop-specific FAO method illustrated here.

With regard to land evaluation for sweet potato, potassium (K) is recognized as an important nutrient for sweet potato (Goodbody and Humphreys 1986), but it is not individually evaluated in the commonly used land evaluation methods.

Applying land evaluation on a database of the **past** environment is even more complicated. Often the database is not detailed enough and many items remain at least highly hypothetical.

Precise climatic monthly data do not exist for the past. Based on palynological data, Flenley *et al.* (1991) mention that the Easter Island climate was warm and moist during the past 12,000 years. From the 14<sup>th</sup> to the 17<sup>th</sup> century, Polynesian occupation had an impact on the soilscape but by far not all of these changes can be reconstructed.

Last but not least, we only have access to crop requirement data for present-day cultivars; we don't have any reference data for less-yielding varieties that may have existed in the past.

We also face methodological problems. In order to grasp past land use systems, an evaluation of the physical resources is not sufficient.

In the Polynesian chiefdom society, agriculture must have played an important economic role (Stevenson and Haoa 1999; Stevenson *et al.* 1999). Good agricultural production meant surplus food and hence enabled chiefs to build monumental religious temples. But how was this achieved?

- Examples from New Guinea showed that people prefer to spread the risk yield rather than getting an optimal yield. They would use different types of land in order to ascertain sufficient yield.

- Though the contrary has mostly been pretended for the Easter Island, ethnographical studies show that people might have been aware of sustainability.

- Also what we call "irrational" behavior, like handling caterpillar pests by means of communicating with those animals instead of extinguishing them (Handy and Handy 1991:146), should not be overlooked.

So, being aware of all these aspects, we need an open-minded approach in order to adequately assess past land use.

## OPEN-MINDED APPROACH

Especially because oral transmission on Easter Island was interrupted due to nearly complete extinction of the population during the 18<sup>th</sup> and 19<sup>th</sup> centuries, field research is of utmost importance to estimate the past data as precisely as possible.

We need appropriate analytical methods for volcanic ash soils. It is also extremely important to collect indigenous knowledge about soil and crop management.

Multivariate statistical models, based on present data, but adapted to past data, might give trustworthy results. When processing the different variables, we should work within a certain range instead of using mean values.

Soils, ecosystems and their interference with humans are

very complex. In the land evaluation procedure, we should be ready to face this challenge!

## CONCLUSIONS

The testing of land evaluation methods at the level of two soil profiles of the La Pérouse area shows that there is need for a much more comprehensive and reliable database. The main constraints are related to:

- Soils can present more than one type of mineralogy within the profile;
- Routine analytical data are not always reliable, particularly the clay content and cation exchange capacity analyses for soils developed in volcanic sediments;
- In these soils, phosphate retention capacity may be one of the most important constraints for chemical fertility, yet this soil characteristic is not included in the list of data needed for the applied FAO Land Suitability Classification;
- For sweet potato, potassium is an important nutrient, but this element is not handled separately in the applied FAO Land Suitability Classification;
- Information about past environmental conditions, particularly about climate and soils, is vague;
- Knowledge about the past indigenous farming systems is still largely missing.

It is very important to be aware about these problems, but such constraints should not stop further research in land evaluation for past crop growth on Easter Island. Besides better-adapted soil analytical methods, it is recommended to focus on the following research orientations.

- As oral transmission on the island was interrupted due to the nearly complete extinction of the population during the 18<sup>th</sup> and 19<sup>th</sup> centuries, field research is of utmost importance to estimate as precisely as possible the past data on climate, soils and land use systems.
- It is extremely important, and urgent, to collect the indigenous knowledge on crop growth that is still present on the island.
- Multivariate statistical models, based on present data, but adapted to past data, might give trustworthy results. When processing the different variables, we should work within a certain range instead of using mean values.

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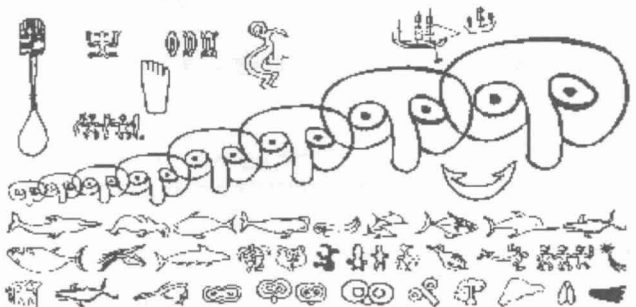


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